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ANALYSIS OF ENVIRONMENTAL ASSESSMENT PROCEDURES DURING OTH
EMULATOR TEST FLIGHTS

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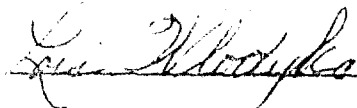
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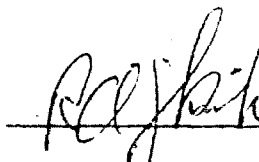


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CONT as due to difficulties in mode identification, when the E mode was dominant. The analysis shows that the MUF determination from mid-point vertical incidence ionograms provides acceptable frequency selection criteria for radar management.

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1.0 INTRODUCTION

The effective management of an OTH-B radar depends on a knowledge of the ionosphere near the reflection point, typically some 800 to 1200 km down range from the radar. In the past, most radar systems depended on a description of the ionosphere using only vertical incidence (VI) soundings made at the radar site. This limits the effectiveness of the frequency management operation in that the ionosphere sensed by the VI sounder is removed from the reflection region. For example, with the radar looking east, the VI sounder colocated with the radar measures at any given time ionospheric conditions which occurred (assuming the same ionospheric diurnal changes at both sites) earlier in the vicinity of the reflection point. At transition times, e.g. sunrise, this difference can become very important. Extrapolation into the future is therefore required, if one relies only on the colocated sounder.

The east coast OTH-B radar located in central Maine has addressed this problem by deploying several VI sounders out in the coverage region at available island locations. For the east coast radar system these remote sounding sites are located at Goose Bay, Labrador, Argentia, Newfoundland and Bermuda. These data, produced by the Air Weather Service Digisonde network, are planned to be available directly to the environmental assessment position located in the radar operations room in Bangor, Maine.

In order to gain confidence in this concept of using remote VI sounders for frequency management, a comparison was made between the predicted maximum usable frequencies (MUF's), derived from the remote VI and transmission curve overlays, and the measured maximum frequencies using oblique ionograms transmitted from the radar site to the AFGL KC-135 aircraft.

In late April and early May, 1987 propagation experiments were carried out in support of the OTH-B radar program. The primary purpose of these experiments was to evaluate the performance of the "target emulator" located at Argentia, Newfoundland. This evaluation required two flights of the AFGL Airborne Ionospheric Observatory (AIO) at ranges varying from 1200 km (overhead Argentia) to some 2000 km from the radar. On each flight the AIO served as a target to be compared to the emulator transmissions.

These flights appeared very useful for the acquisition of a vertical sounding and oblique propagation data base to be used for analyzing Environmental Assessment (EA) performance. Therefore AFGL and the University of Lowell Center for Atmospheric Research (ULCAR) developed a plan to monitor the ionospheric propagation modes during the flight and to compare these observations with the operationally determined radar frequency using the MUF values scaled from the vertical incidence (VI) ionograms made routinely at Argentia.

These Argentia vertical ionograms are routinely and automatically scaled and communicated by telephone to the radar operations site at Bangor. At the radar, additional processing is performed and the results, in terms of suggested operating frequencies or as inputs to the Coordinate Registration (CR) process, are made available to the EA operators.

The special oblique propagation ionograms (one way path) to the aircraft are not usually available to the radar operators. They must make use of a scaled VI which, preferably, would be a VI located some 1000 km down range from the radar rather than using the VI colocated with the radar. These test measurements represent a good chance to evaluate the effectiveness of these remote sounders.

2.0 ANALYSIS

2.1 Data Scaling

The approach used here to evaluate the remote vertical ionogram technique was to scale maximum usable frequencies (MUFs) from the Argentia VI using all the available modes, in this case 1F1 and 1F2, for the duration of the flight and to compare these results with the maximum observed frequency (MOF) for the respective modes scaled from the oblique ionograms made between the radar and the aircraft.

The scaled frequencies are shown in Figures 1 and 2 for the flights on 28 April and 1 May 1987, respectively. Figures 1a and 2a are for the F1 modes while Figures 1b and 2b are for the F2 modes. The VI ionograms were available every 10 minutes. The scaled MUFs used an M-factor which depended on the range to the AFGL aircraft. The range to the aircraft varied with time during each mission as shown in Figures 3 and 4. The M-factor scaling was carried out to the nearest 100 km for each aircraft range.

The oblique ionograms between the radar site and the AFGL aircraft were made on a five minute schedule. The time resolution is sufficient to compare the two methods. The maximum observed frequency (MOF) for each mode was scaled from the oblique ionograms. The scaled MOF values are also shown in Figures 1 and 2. Although the general variation is the same for both flights there is an apparent bias between the oblique results at the scaled MUF's for the F1-mode. The measured MOF values are consistently higher than the MUF's derived from the VI and this result required further investigation.

F1 MUF/MOF COMPARISON EMULATOR FLIGHT: 28 APRIL 1987

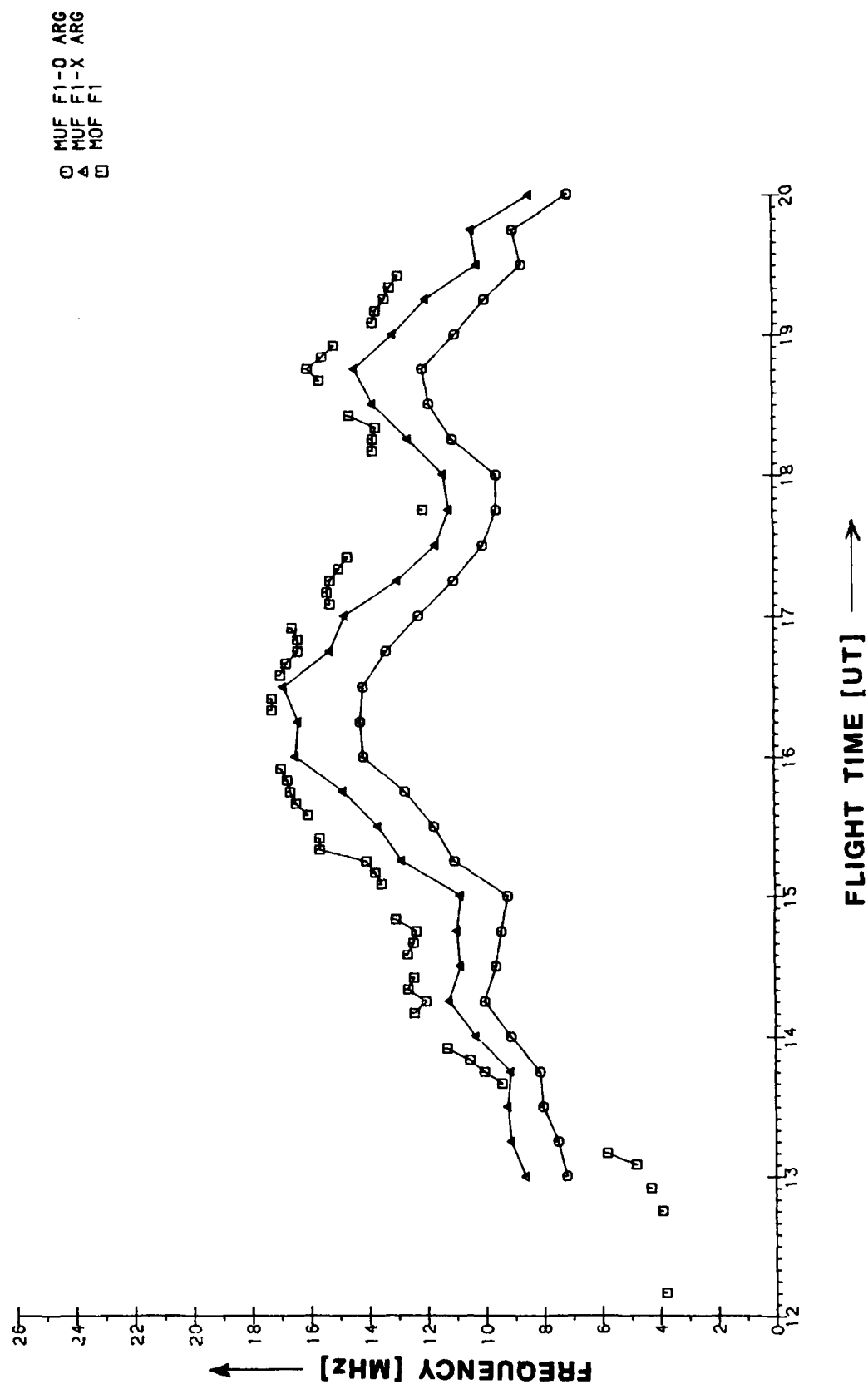


Figure 1a. MUF and MOF vs. Time
28 April 1987 F1-Mode

F2 MUF/MOF COMPARISON
EMULATOR FLIGHT, 28 APRIL 1987

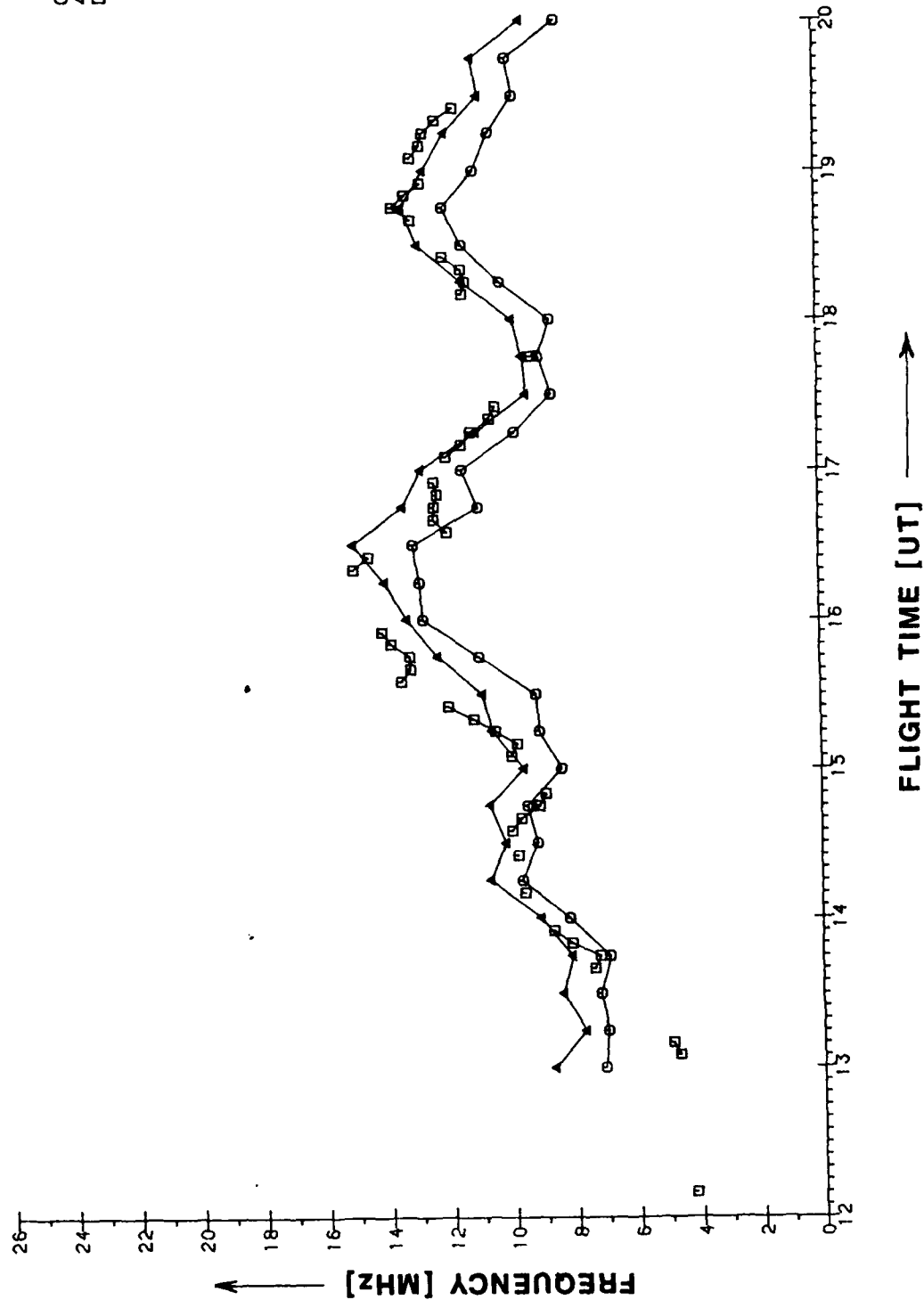


Figure 1b. MUF and MOF vs. Time
28 April 1987 F2-Mode

F1 MUF/MOF COMPARISON EMULATOR FLIGHT, 1 MAY 1987

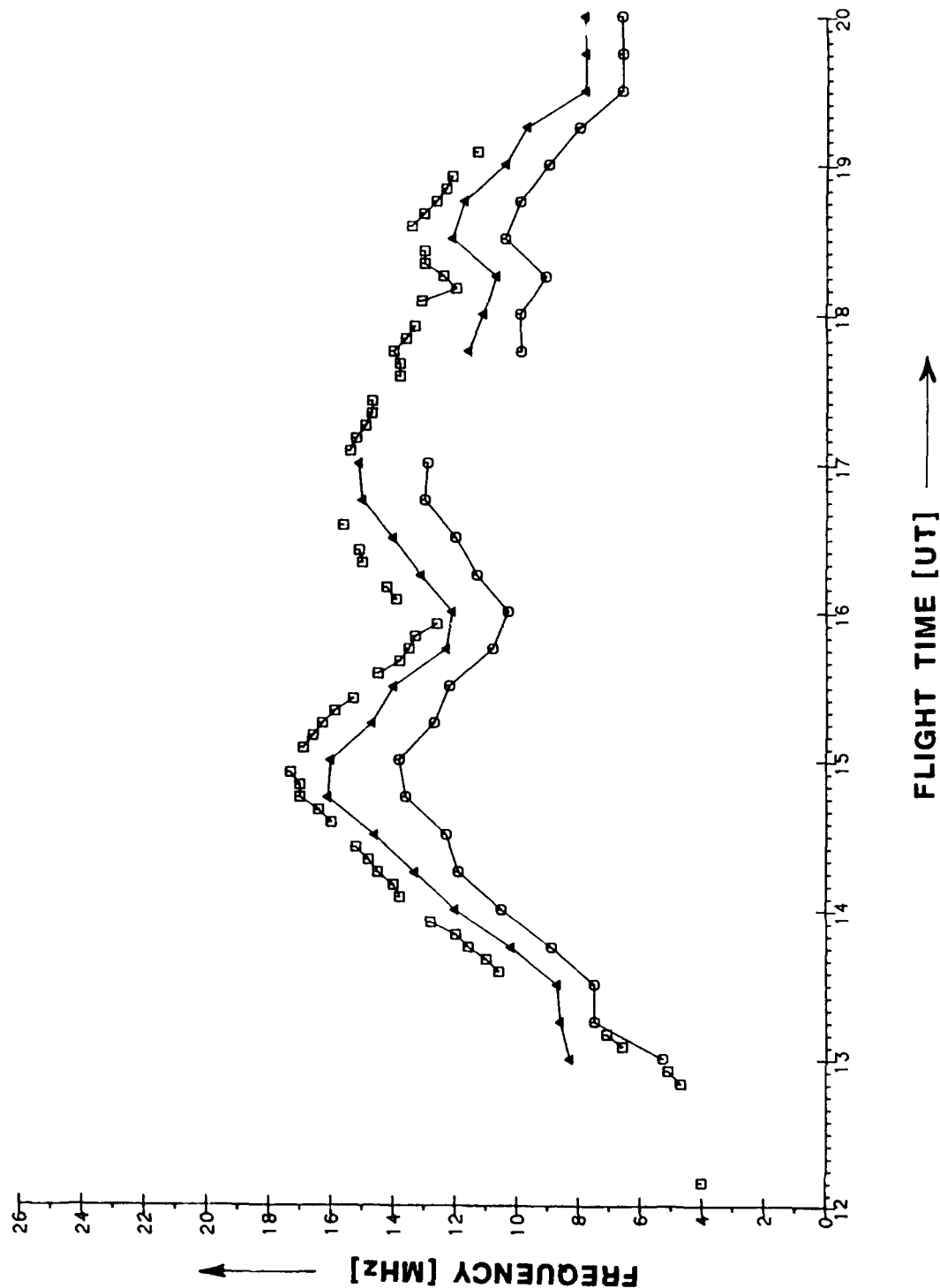


Figure 2a. MUF and MOF vs. Time
1 May 1987 F1-Mode

F2 MUF/MOF COMPARISON
EMULATOR FLIGHT, 1 MAY 1987

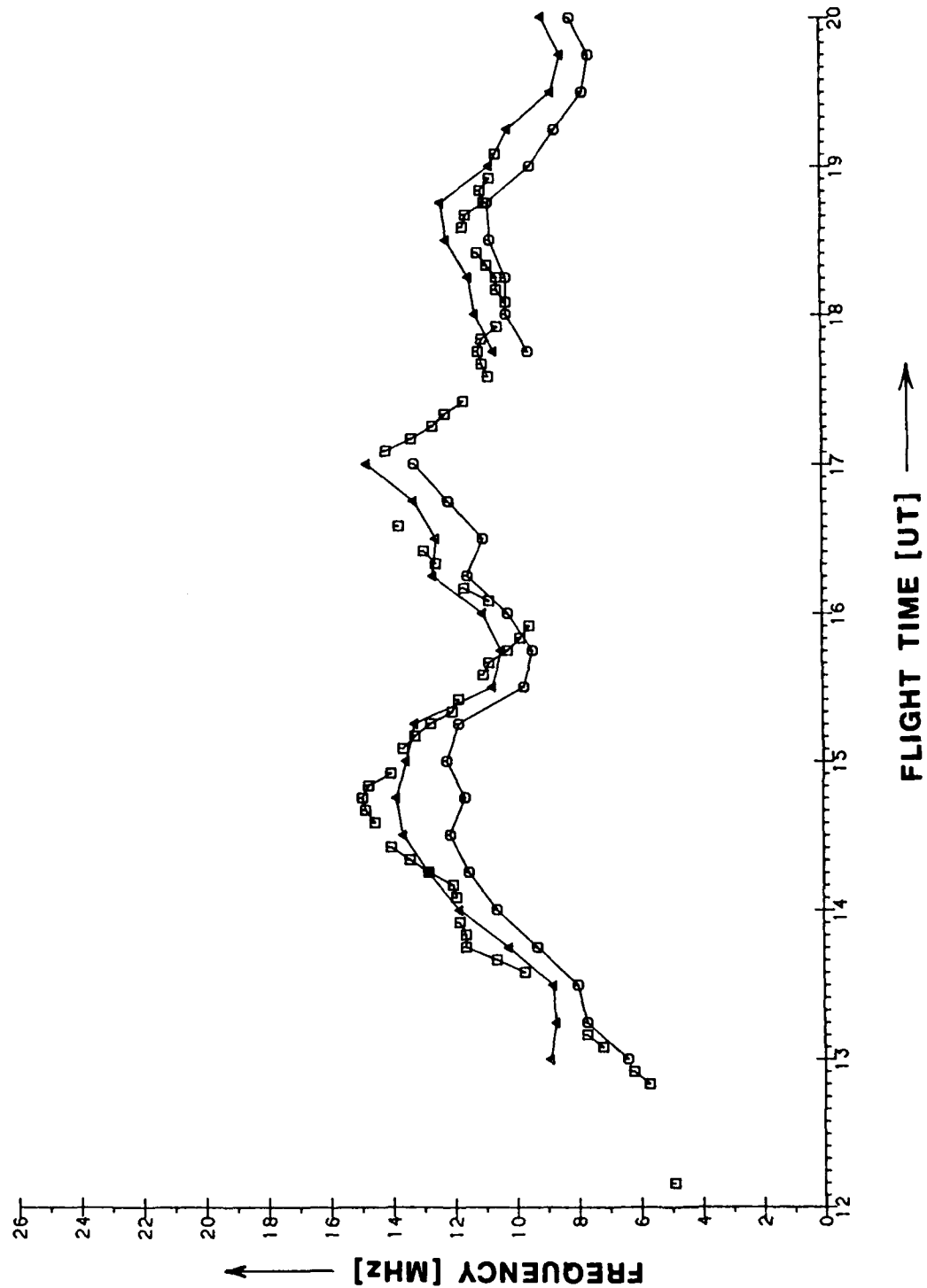


Figure 2b. MUF and MOF vs. Time
1 May 1987 F2-Mode

**GROUND RANGE BANGOR TO AFGL AIRCRAFT
EMULATOR FLIGHT, 28 APRIL 1987**

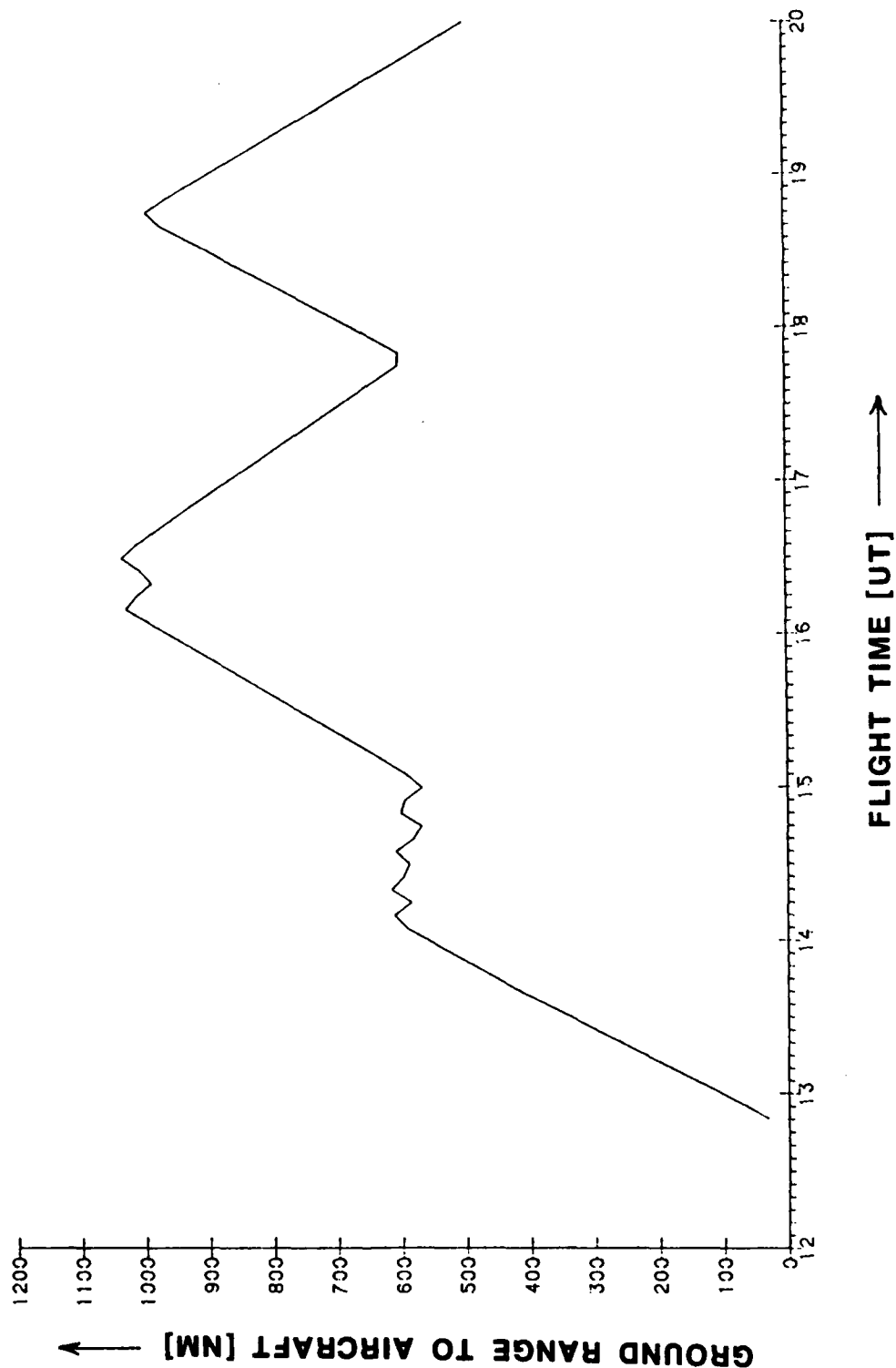


Figure 3. Aircraft Ground Range vs. Time
28 April 1987

**GROUND RANGE BANGOR TO AFGL AIRCRAFT
EMULATOR FLIGHT, 1 MAY 1987**

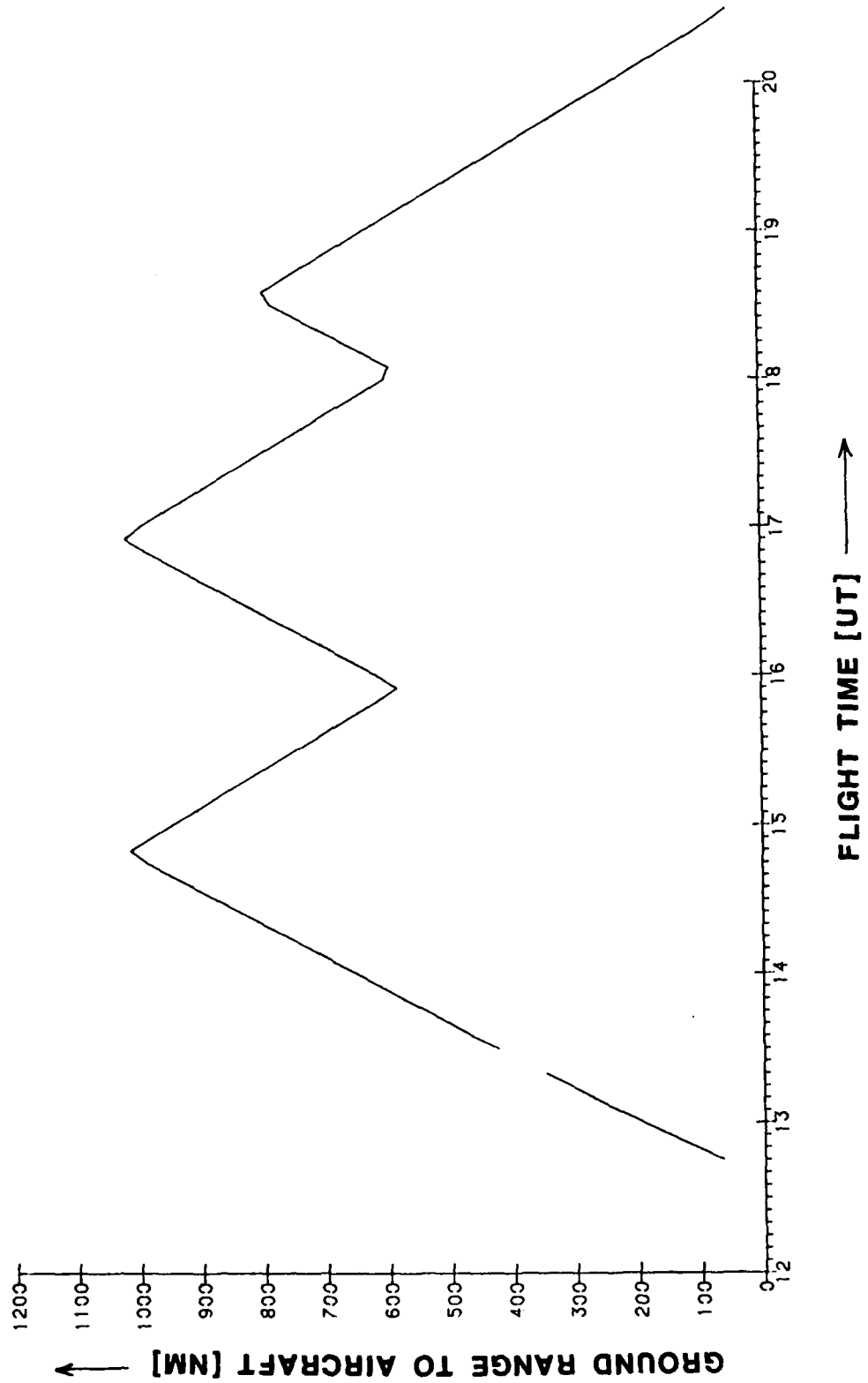


Figure 4. Aircraft Ground Range vs. Time
1 May 1987

2.2 Oblique Ionogram Simulation

A straightforward approach to analyzing this bias in the data was to simulate the oblique propagation modes for selected periods during the flight. To do this we used the Argentia vertical ionograms to derive electron density profiles. We selected times when the AIO was at its maximum range from the radar so that Argentia was as close as possible to the midpoint of the path. These times are as follows:

28 April 1987

<u>UT</u>	<u>A/C Range (km)</u>
1544	1680
1559	1743
1614	1854
1629	1887
1644	1752

The electron density profiles for these times were used with our 2-D ray tracing program to compute simulated oblique ionograms without considering gradients.

An example of one of the simulated oblique ionograms for 1544 UT on 28 April 1987 is shown in Figure 5. This selected example is typical and provides insight to the cause of the systematic differences between the scaled MUF's and MOF's for the F1 mode. The main cause seems to lie in the nature of the F1 and E layers for the given time of day and range of the aircraft. Using our simulations it would be difficult to distinguish between these two modes and it is very likely that when the oblique ionograms were scaled, without the benefit of the simulation, the E-MOF was mistakenly identified as an F1 mode. This problem was made worse considering the quality of the oblique ionograms made aboard the AIO. All of the traces on the ionograms are approximately double the equivalent pulse width in thickness

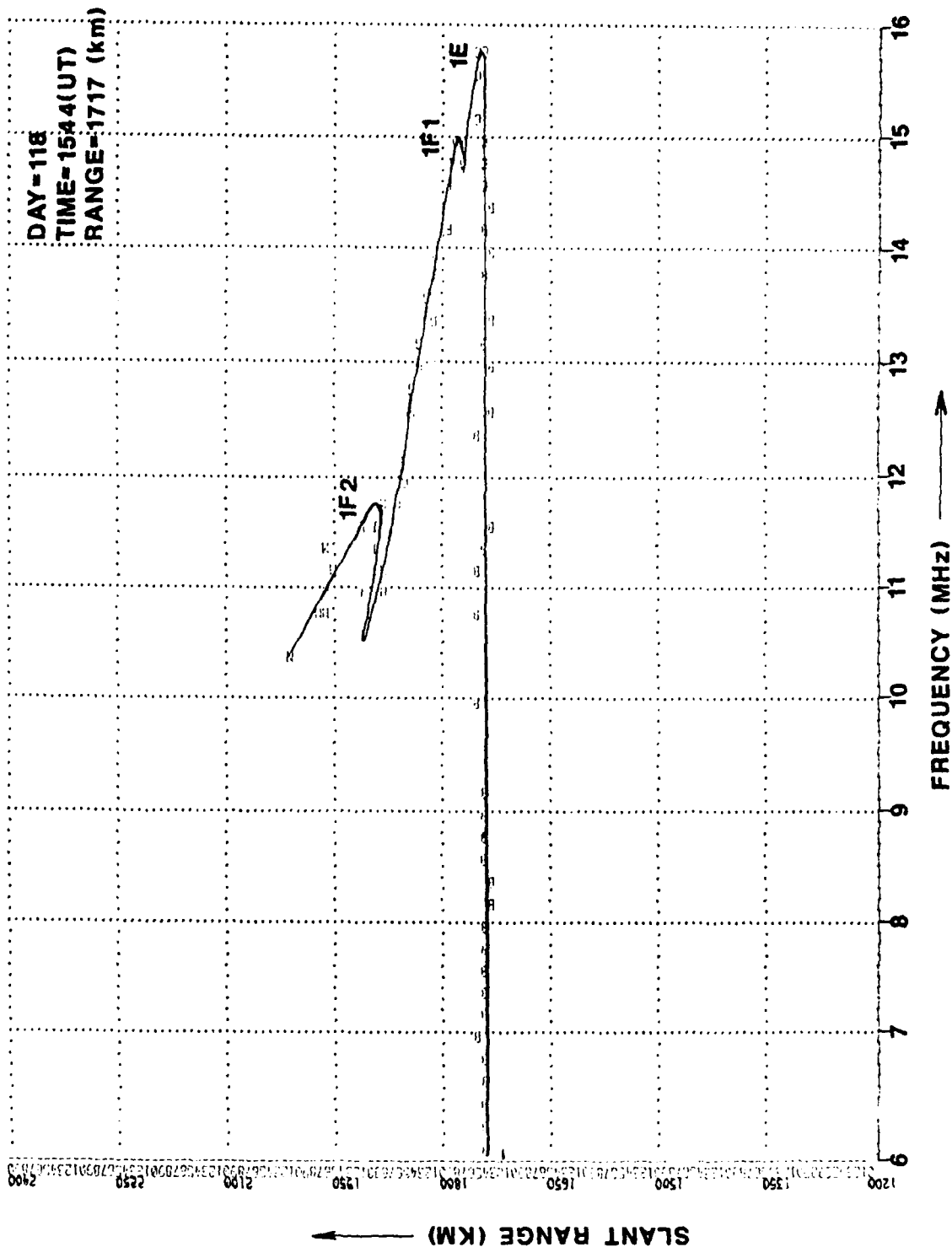


Figure 5. Simulated Oblique Ionogram, OTH Radar to A10; 28 April 1987, 1544 UT. Simulation shows a small time delay difference between the 1F1 and the 1E modes. This led to difficulties in mode identification during MOF evaluation.

because each signal reaching the aircraft arrives by three modes with different time delays: direct, ground reflected and a hybrid mode that combines the direct and ground reflected paths (see Figure 6). The time delay difference between the three modes is small. As we shall show shortly, the system is unable to resolve these modes and records widened traces. For a typical aircraft altitude of 40,000 feet, the time delay difference of the direct and ground reflected mode is of the order of 10 ns, depending somewhat on the elevation angle of the incoming rays.

Using the actual oblique ionograms, it is possible to estimate the range resolution inherent in the chirp sounder processing. This is an older system and the details of the processing are no longer available. Full scale on the ionograms represents 1500 km and a range resolution of 1/200 of full scale is possible. This leads to a 7.5 km resolution.

Since this is of the order of the time delay separation of the multiple ray paths to the aircraft broadening of all the oblique ionogram traces is unavoidable, leading to smearing of minor cusps, such as the simulated 1F1 cusp shown in Figure 1 and giving rise to the discussed misidentification of the mode of the scaled MOF's.

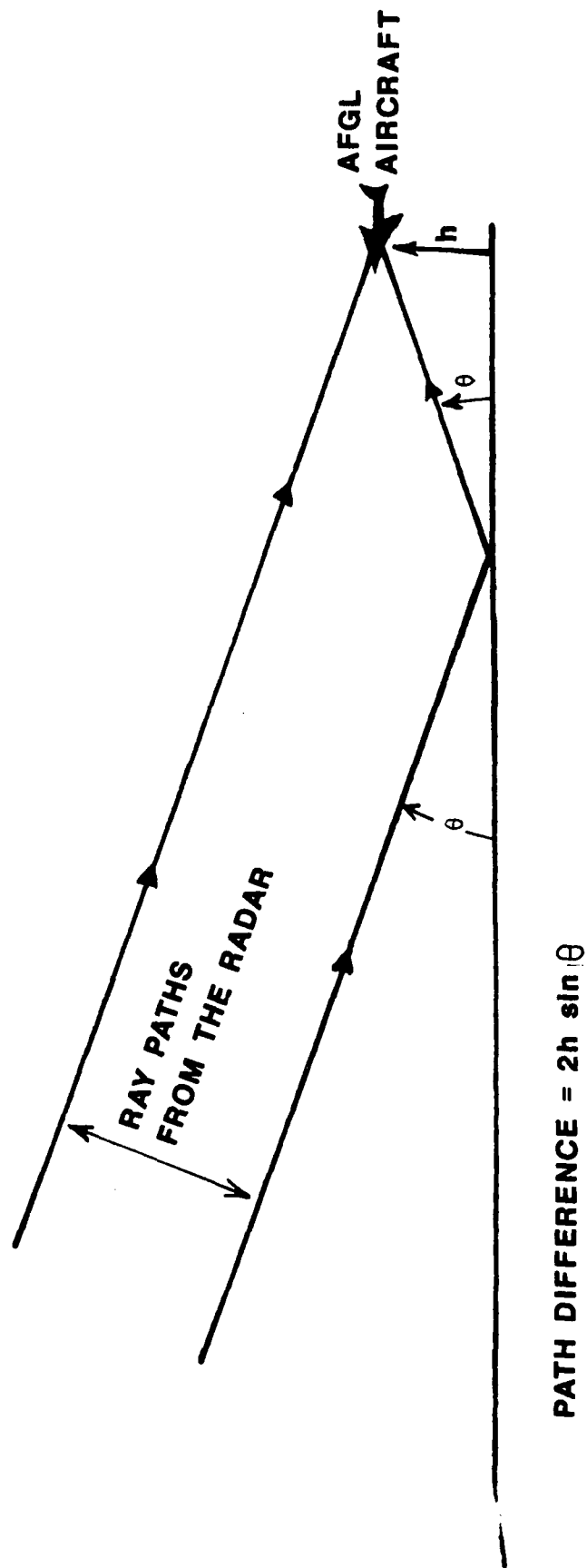


Figure 6. Schematic Description of the Direct and Ground Reflected Modes to an Elevated Target

3.0 COMPARISON OF MUF AND MOF

3.1 F2 Modes

Figures 1 and 2 compare the MUF with the MOF for the F2 modes for both flights. These flights took place during the midday period from 1300 UT to 2000 UT (subtract 3.5 hours for local time at Argentia, NF). This is a relatively stable period with small gradients in the ionosphere. The MUF-MOF comparison is good at these times with deviations never exceeding 1 MHz and a mean deviation of less than 0.5 MHz.

The MUF data scaled from the Argentia VI's used overlays with range parameters which tracked the movement of the aircraft to within 100 km. These overlays were used separately on the O and X traces to produce the two MUF curves in Figures 1 and 2. An unresolved question is still the appropriateness of applying the transmission curve overlay to the VI X-mode to determine the X-MUF.

The identification of the X-mode MUF is necessary as it represents the highest propagating frequency to any specified distance. The subject of oblique X-modes has not been treated extensively in the literature, though Davies (Ionospheric Radio Waves, p. 320, 1968) has estimated the O-mode, X-mode MUF differences for radio paths with varying the bearing angles with respect to the magnetic meridian.

Using the data from this experiment, it is not possible to determine whether a better fit is achieved with the O or X-mode MUF's. More work, both experimental and theoretical, is necessary to resolve this question and then with this data it may be possible to develop new techniques for scaling the VI that more correctly predict the operating frequency for a particular desired radar coverage.

Although these measured differences are small for the F2 mode during the midday period, this will not necessarily be the case at other times of day when gradients become more important. This would suggest that these EA flights ought to be carried out at other times and seasons. More recent measurements, which will not be reported here, have been valuable in developing methods for frequency management during the sunset transition periods (Sales and Buchau, private communication, 1987).

3.2 F1 and E-Modes

A comparison of 1F1 MOF values with MUFF1 estimates derived from Argentia VI data shows a systematic bias ($MUF < MOF$) by between 1 and 2 MHz. The simulation of propagation ionograms using Argentia VI data points to the misidentification of the actually dominant 1E mode as an 1F1 mode as an explanation. The aircraft data quality, however, does not permit to produce a good fit between reinterpreted MOF and MUF of the 1E mode.

Because of these scaling difficulties, it is not possible to evaluate the VI-transmission curve technique for these modes. In addition we have difficulty in identifying and separating Es modes from normal E-modes and thus cannot evaluate the effectiveness of this method when the radar transmissions are propagating by these modes.

4.0 CONCLUSIONS AND RECOMMENDATIONS

These experiments have shown that there are times when the ionosphere is relatively stable with small gradients, when using a "remote site" VI can be effective in frequency managing an OTH-B radar. At these times and in the directions where the VI sounder is near the midpoint of the path, this method works well.

On the other hand, this analysis has raised several additional questions that need answering before we can be confident that the remote VI technique can be relied on for radar frequency management. The following itemized list briefly describes areas that need further investigation.

1. Most important is the question of how to correctly account for the X-mode contribution to the frequency management. Calculations and modeling can be carried out that characterize oblique X-mode propagation so that it can be used as an effective tool for frequency management of the radar.
2. Simplified methods should be developed to take into account the effect of natural ionospheric gradients. These gradients, largest during the sunset and sunrise periods, will affect the MUF determination using the current standard method which employs only the VI sounding and transmission overlay.
3. To the greatest extent possible, advantage should be taken of all AFGL AIO missions which fly in the vicinity of the radar coverage. These flights, with proper coordination, can be used to evaluate frequency management performance under a variety of ionospheric conditions. These should include time of day, season and radar coverage.